Chapter 2
affected environment

NTRODUCTION

'his chapter describes the existing physical, biological and ;ocioeconomic conditions in and adjacent to the Jackpile-Paguate uranium ıine. The information in this chapter provides the basis for the ıssessment of impacts made in Chapter 3.

lap 1-2 in Chapter 1 shows the principal features of interest in and ıround the minesite. These features are also listed in Table 2-1. Table !-2 defines terms that are used throughout this document. These lefinitions apply specifically to this EIS and should not be confused vith other definitions for these terms.

MINING OPERATIONS

Operations at the Jackpile-Paguate uranium mine were conducted from three open pits and nine underground mines. Open-pit mining was conducted predominantly with large front-end loaders and haul trucks. The overburden, consisting of topsoil, alluvium, shale and sandstone was blasted or ripped, removed from the open pits, and placed in waste dumps. The uranium ore was segregated according to grade and stockpiled for shipment to the mill. In the later years of mining, material conducive to plant growth was stockpiled for future reclamation. Ore-associated waste and some overburden was also placed in the mined-out areas of the pits as backfill.

Underground mining was conducted by driving adits, or declines, to the ore zones. Drifts were driven through the ore zone, and the ore removed by modified room-and-pillar methods. Ventilation holes were drilled to maintain a fresh air supply. Mine water was collected in sumps and pumped to ponds in the open pits. Waste rock was placed in waste dumps, and the ore was stockpiled for shipment to the mill.

Surface Disturbance

During the 29 years of mining activity, approximately 2,656 acres of natural ground were disturbed by mine operations, as indicated in Table 2-3 and on Visual A.

Open Pits

The Jackpile, North Paguate and South Paguate open pits make up about 40 percent of the total disturbed acreage at the minesite (Figure 2-1). Approximately 101 million tons (63.6 million cubic yards) of backfill, composed principally of ore-associated waste with some overburden, have been returned to the pits. Due to irregular topography, the pits vary in maximum depth as follows: Jackpile 625-feet deep; North Paguate-200 feet deep; and South Paguate-325 feet deep.

The most prominent features within the excavated pits are the pit walls (also called highwalls), which are composed principally of shale with some intermixed sandstone beds. The overall slope angle of the pit walls ranges between 49 and 55 degrees (Figure 2-2).

TABLE 2-1

PRINCIPAL FEATURES OF INTEREST IN AREA OF JACKPILE-PAGUATE URANIUM MINE

Feature	Description
Anaconda Mining Leases	Three leases totaling approximately 7,868 acres.
NM Highway 279	Realignment is being proposed to eliminate a hazardous section of this State highway that presently passes around the mine. This realignment is not part of the overall reclamation project.
Paguate Reservoir[a]	Constructed south of the mine area in 1940, now almost completely silted in.
Rail Spur	Constructed by Anaconda on a right-of-way across Pueblo of Laguna land.
Rio Paguate and Rio Moquino	Small perennial rivers that join within the minesite for an average combined discharge of 1.2 cubic feet per second.
Village of Laguna	Laguna Indian village with 1,565 residents.
Village of Paguate	Laguna Indian village with 1,435 residents located approximately 1,000 feet from the mine.

Note: [a] Paguate Reservoir is sometimes referred to as Quirk or Mesita Reservoir.

TABLE 2-2

TERMS USED IN THIS EIS

General Term	Definition	Components
Jackpile Sandstone	The ore-bearing unit at the Jackpile-Paguate uranium mine	Barren waste [less than .002 percent uranium (U_3O_8)][a/]
		Ore-associated waste (.002 to .019 percent U_3O_8)[a/]
		Protore (.02 to .059 percent U_3O_8--refer to Glossary)[a/]
		Ore (greater than .06 percent U_3O_8)[a/]
Overburden	Any material that overlies the ore-bearing unit	Topsoil, Alluvium, Mancos Shale, Tres Hermanos Sandstone, Dakota Sandstone
Soil	Material used as plant-growth medium during revegetation	Topsoil, Alluvium, Pulverized Tres Hermanos Sandstone

Note: a/This percentage range applies to this EIS only--refer to the Mineral Resources section of this chapter for an explanation.

TABLE 2-3

JACKPILE-PAGUATE URANIUM MINE DISTURBED AREAS

Feature	Acres
Open Pits	
Jackpile	475
North Paguate	140
South Paguate	400
	1,015
Waste Dumps	
Jackpile area	718
North Paguate area	192
South Paguate area	356
	1,266
Protore Stockpiles	
Total mine area, excluding open pits	103
Topsoil Stockpiles	
TS-1	21
TS-2(A and B)	11
TS-3[a]	(19)
	32
Other Disturbed Areas	
Depleted ore stockpiles[b]	50
General area disturbance (includes buildings, parking lots)	66
Roads	88
Rail spur and miscellaneous areas	36
	240
TOTAL ACRES DISTURBED	2,656

Source: Anaconda Minerals Company 1982.

Notes: [a]Topsoil stockpile TS-3 is located on South Dump and therefore does not constitute additional acreage of disturbed natural ground.
[b]Refers to former stockpile areas in which the ore was either relocated to the open pits or shipped to the mill.

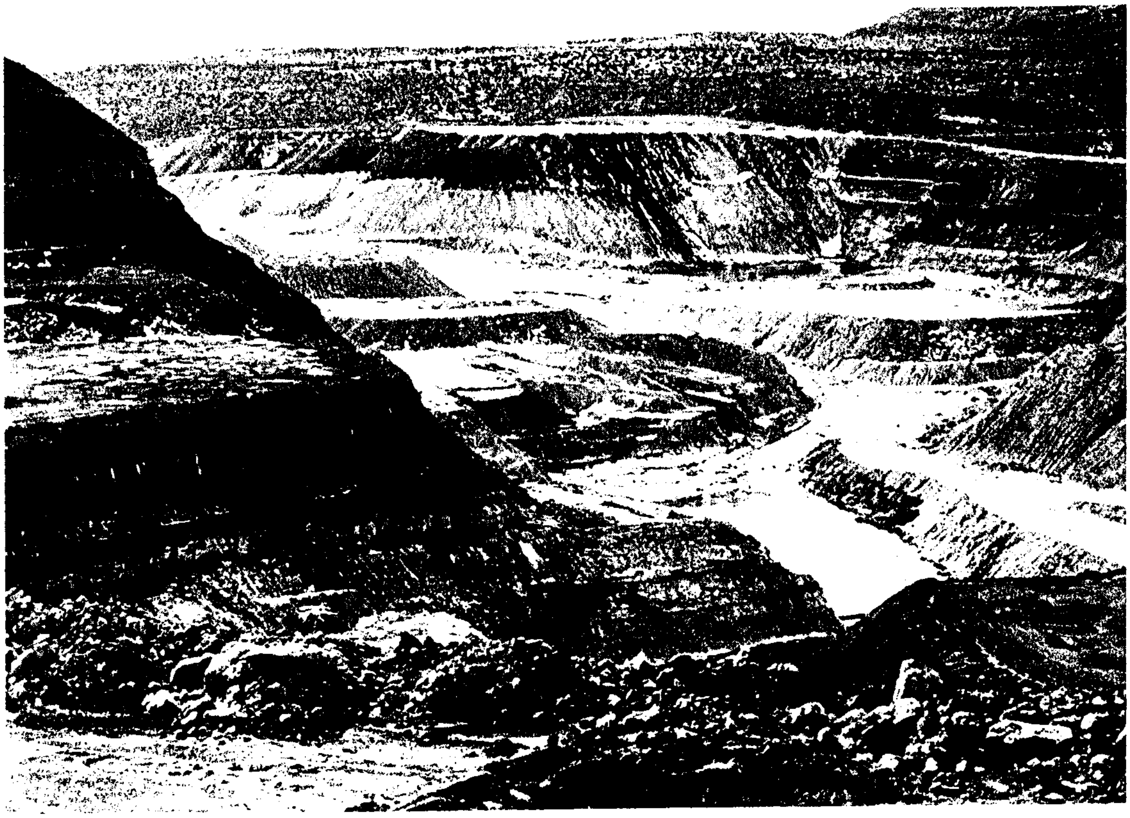

FIGURE 2-1 VIEW SOUTH THROUGH JACKPILE PIT

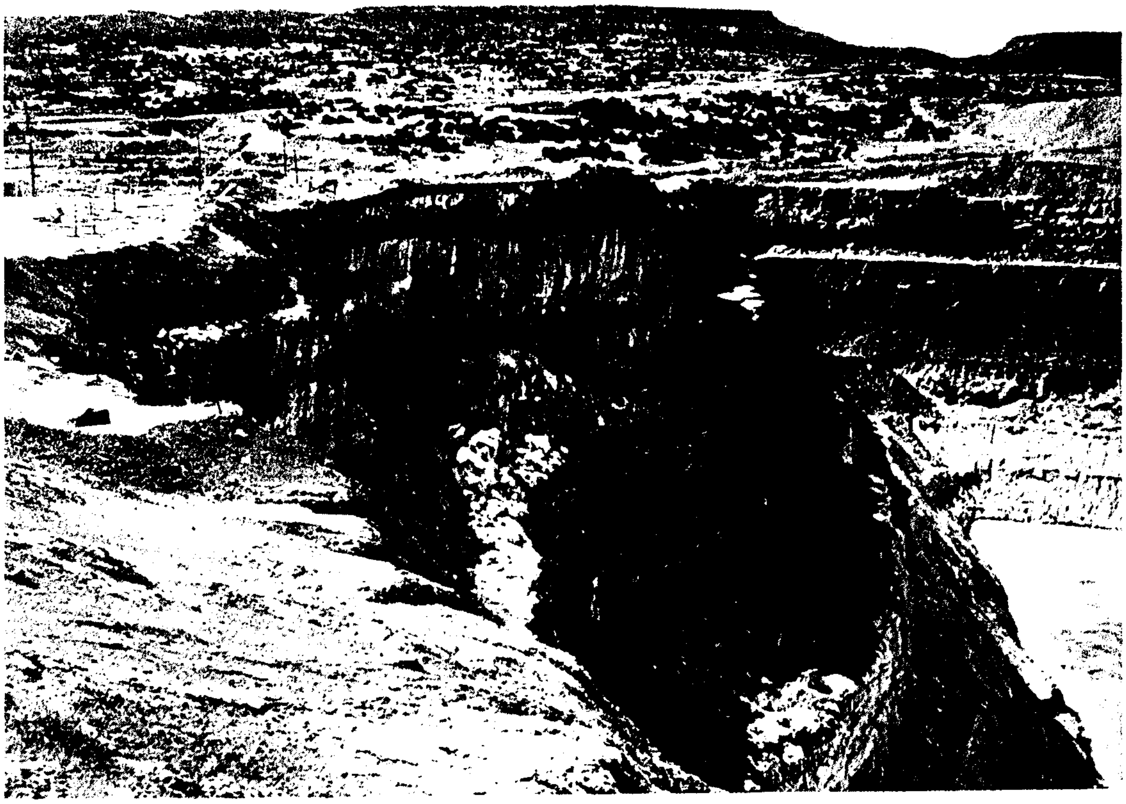

FIGURE 2-2 SOUTH PAGUATE PIT HIGHWALL

Water has collected in the lowest portions of the pits as a result of surface runoff, ground water recovery and water discharged from the underground operations (Figure 2-3). As of April 1984, water levels in the pits ranged between elevations of 5830' and 5959'.

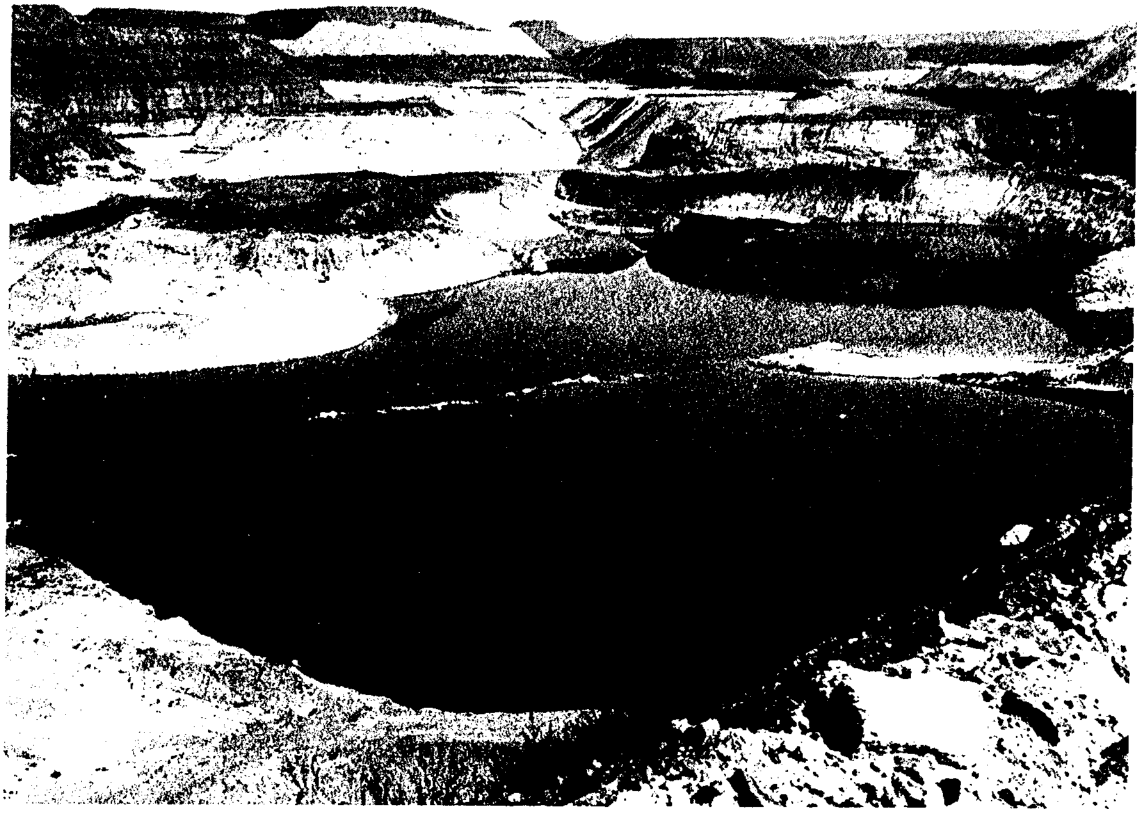

FIGURE 2-3 PONDING IN NORTH PAGUATE PIT

Waste Dumps

The minesite contains 32 waste dumps that make up about 48 percent of the disturbed area (Figure 2-4). The dumps are composed of Tres Hermanos Sandstone, Mancos Shale, Dakota Sandstone, and both barren and ore-associated Jackpile Sandstone. Characteristics of the dumps, including previous reclamation performed, are presented in Table 1-4 (Chapter 1).

Protore Stockpiles

Located outside and inside of the pits are 23 protore stockpiles (Figure 2-5 and Table 2-4). The protore that lies outside the pits covers approximately 100 acres and contains approximately 7.2 million cubic yards of material. Those stockpiles that lie inside the pits contain about 3.1 million cubic yards of matieral but do not constitute additional acreage of disturbed ground. The stockpiles are generally segregated according to grade, but some grade variation exists within each stockpile.

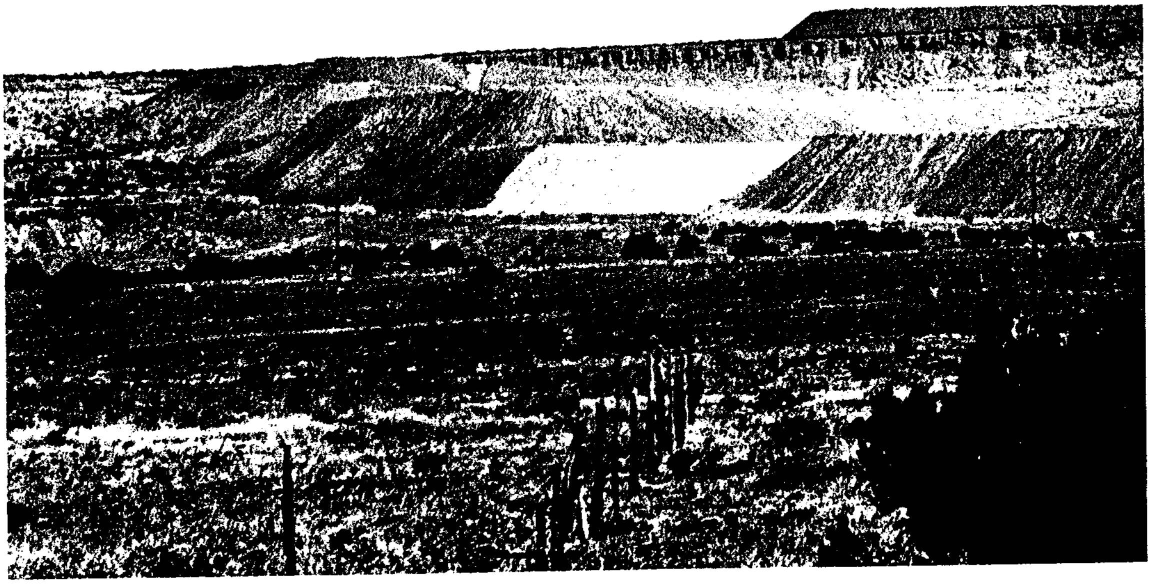

FIGURE 2-4 WASTE DUMPS ON NORTH SIDE OF MINE

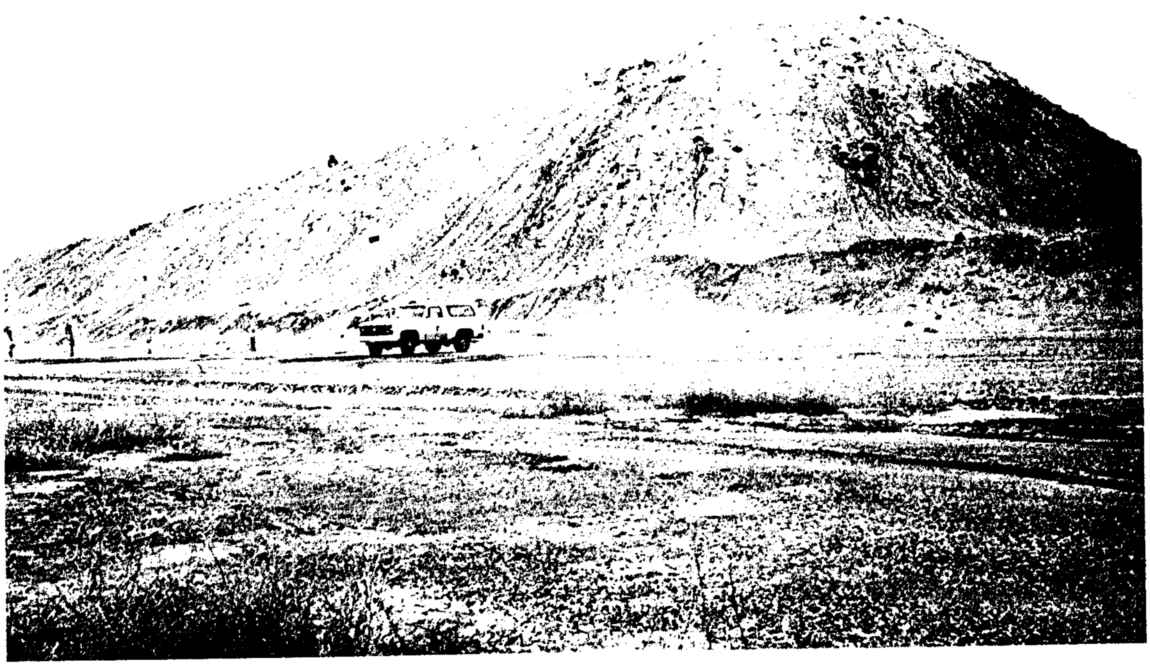

FIGURE 2-5 PROTORE STOCKPILE SP-1

TABLE 2-4

PROTORE STOCKPILES AT THE JACKPILE-PAGUATE URANIUM MINE

Area	Stockpile Designation	Volume (cubic yards)
Jackpile Mine Area	J-1	328,950
	J-1A[a]	
	J-1-A	1,673,500
	JLG	
	SP-1	353,700
	J-2	156,860
	SP-6-A	1,517,000
	SP-6-B	
	SP-17BC	18,100
	17-E[a]	660,000
North Paguate Mine Area	1-B	993,760
	1-E[a]	154,500
	2-E	255,400
	10-Dike	23,920
	SP-1	620,400
	SP-1-C	284,720
	SP-2-C	1,223,790
	SP-2-D	122,660
South Paguate Mine Area	1-D[a]	
	PLG	648,700
	PLG-1	
	4-1	154,800
	SP-1-A	1,161,830
TOTALS	23 stockpiles	10,352,590

Source: Stockpile designations and locations Anaconda Minerals Company 1982; volumetric calculations Anaconda 1982 and BLM 1984.

Note: [a] Stockpiles located within pits themselves.

Topsoil Stockpiles

During the later years of mining, all Tres Hermanos Sandstone and alluvium encountered during surface mining was stockpiled for future reclamation operations. These stockpiles contain approximately 3.1 million cubic yards of material (BLM 1984).

Surface Facilities

The minesite contains various buildings, structures and surface facilities which cover approximately 66 acres (Figure 2-6). Most of the major buildings are constructed on cement slabs with steel frames and sheet metal siding. Many have heating, sewage, electric and drinking water systems. The condition of the buildings varies considerably, but many are in good condition. A list of these facilities located on leases No. 1 (Jackpile) and No. 4 is shown in Table 2-5.

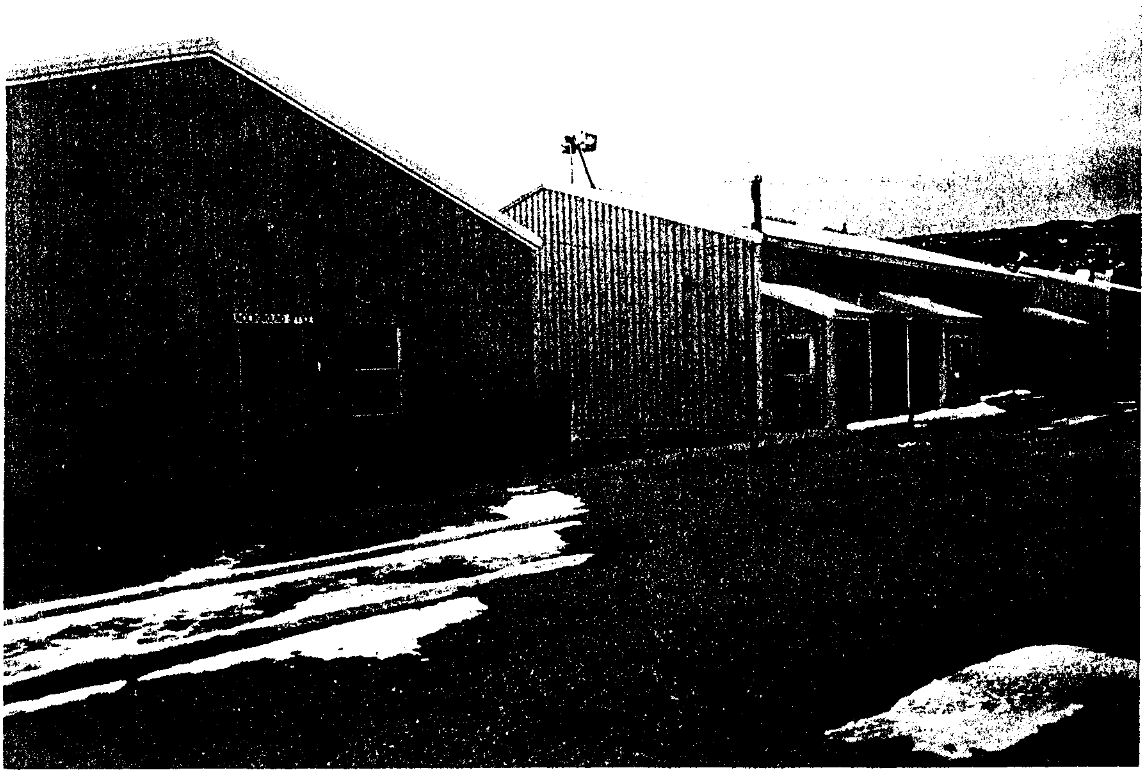

FIGURE 2-6 P-10 MINE BUILDINGS

The minesite also contains a rail spur that connects the site to the main east-west line of the Santa Fe Railroad, 5 miles south. The spur was used to transport ore from the mine to Anaconda's Bluewater Mill near Grants, New Mexico.

TABLE 2-5

STRUCTURES AND FACILITIES LOCATED ON LEASES NOS. 1 AND 4

Lease/Feature	Coverage
Lease No. 1 (Jackpile)	
Buildings-Structures	
1. Geology building	4,000 sq. ft.
2. School building	1,500 sq. ft.
3. Miners' training center	2,730 sq. ft.
4. Guardhouse (2)	144 sq. ft. each
5. Explosives magazines (3)	100 sq. ft; 1,200 sq. ft.; 180 sq. ft.
6. Maintenance and repair shop	7,000 sq. ft.
7. Repair and electrician's shop	1,260 sq. ft.
8. Welding shop	1,600 sq. ft.
9. Warehouse	3,600 sq. ft.
10. Change house	480 sq. ft.
11. Restroom	320 sq. ft.
12. Safety room and change room	1,116 sq. ft.
13. Mine engineering and housing repair shop	5,000 sq. ft.
14. Fuel service area (mine office)	
a. 2 ea. gasoline pumps	
b. Gasoline storage tanks	
15. Fuel service area (Hamilton)	
a. 2 ea. fuel pumps	
b. 2 ea. underground fuel storage tanks	
16. Surface mining main office	1,116 sq. ft
17. Truck parking lot (includes 20 service stands and 2 small buildings)	
18. Boundary fencing	approx. 14,850 linear ft.
19. Road culverts over Rios Moquino and Paguate (6 ea.)	
20. Concrete crossing (ford) over Rio Paguate near main gate	
Housing	
1. 7 houses	approx. 1,650 sq. ft. each
11 houses	approx. 1,250 sq. ft. each
2. Recreational facilities (includes tennis/basketball courts, misc. playground equipment)	
Utilities	
1. 5 wells, cased with pumps	
a. Jackpile No. 1 - Peerless vertical turbine pumps, electrical service (not activated), building	
b. Jackpile No. 2 - Reda submersible pump, electrical service (not activated), building	
c. Jackpile No. 3 - submersible pump, electrical service (not activated), building	
d. Jackpile No. 4 - submersible pump, electrical service (not activated), building	
e. Jackpile No. 5 - Jensen straight pumpjack, electrical service (not activated), building	
2. Water Distribution Systems and Water Storage Tanks	
a. 600 gallon (1 ea.)	
b. 800 gallon (1 ea.)	
c. 1,000 gallon (1 ea.)	
d. 2,000 gallon (1 ea.)	
3. Housing Sewage Disposal System and Lagoons—2-cell sewage lagoon (fenced)	
4. Powerlines	
a. Poles	
b. Wire line	approx. 16,000 linear ft.
c. Transformers	
5. 3-Phase Substation at Engineering Office	

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TABLE 2-5 (concluded)

Lease/Feature	Coverage
Lease No. 1 (Jackpile) (cont'd)	
Rail Spur	
Railroad spur from rail line (AT & SF) to mine- Materials: 90# rail, ties, hardware, ballast, turnouts and switches, bridge structure and culverts	approx. 5.4 miles long
Lease No. 4	
Buildings-Structures	
1. P-10 underground mine office	4,000 sq. ft.
2. P-10 change house	2,800 sq. ft.
3. P-10 equipment repair shop	1,850 sq. ft.
4. P-10 electric shop	1,900 sq. ft.
5. P-10 storage shed	150 sq. ft.
6. P-10 fenced storage yard	approx. 1.5 acres
7. Carpenter shop	2,520 sq. ft.
8. Paint shop	225 sq. ft.
9. Electric shop	2,520 sq. ft.
10. Welding shop	3,000 sq. ft.
11. Warehouse	10,800 sq. ft.
12. Rebuild shop	1,350 sq. ft.
13. Maintenance and repair shop	12,240 sq. ft.
14. Small storage shed	150 sq. ft.
15. Wash rack and associated buildings	306 sq. ft.
16. Garage	864 sq. ft.
17. Change house	936 sq. ft.
18. Conference hall and office	1,200 sq. ft.
19. Fuel service area, including: a. 2 gasoline pumps b. 1 diesel pump c. 3 fuel storage tanks	
20. Chain-link fenced shop storage yards (2)	approx. 1 to 1.5 acres ea.
21. Chain-link fenced warehouse storage yard (asphalt base)	approx. 1/4 acre
22. Guardhouse (2)	144 sq. ft each
23. Explosives magazine (2 ea.)	600 sq. ft.
24. Stock water tank (south of new shop well)	
Utilities	
1. 2 wells, cased with pumps a. P-10 well, submersible pump, electrical service, cover structure b. New shop well, submersible pump, electrical service, cover structure	
2. Water distribution systems and water storage tanks a. P-10 tank, approximately 1,000 gallon with support structure b. New shop tank, approximately 1,200 gallon with support structure	
3. Sewage disposal system and lagoons. a. P-10 with 3-cell lagoon (fenced) b. New shop system with 3-cell lagoon (fenced)	
4. Powerlines a. Poles b. Wire line c. Transformers	approx. 7,600 linear ft.

Source: Anaconda Minerals Co. 1984.

Note: All building areas are approximate.

Underground Disturbance

Mining was conducted in nine underground mines (Visual A). Five of these mines were permanently plugged and abandoned as part of normal mining operations. The remaining four were operating when overall mining operations were suspended, and each has been temporarily closed for safety (Figure 2-7). Table 2-6 briefly describes each mine.

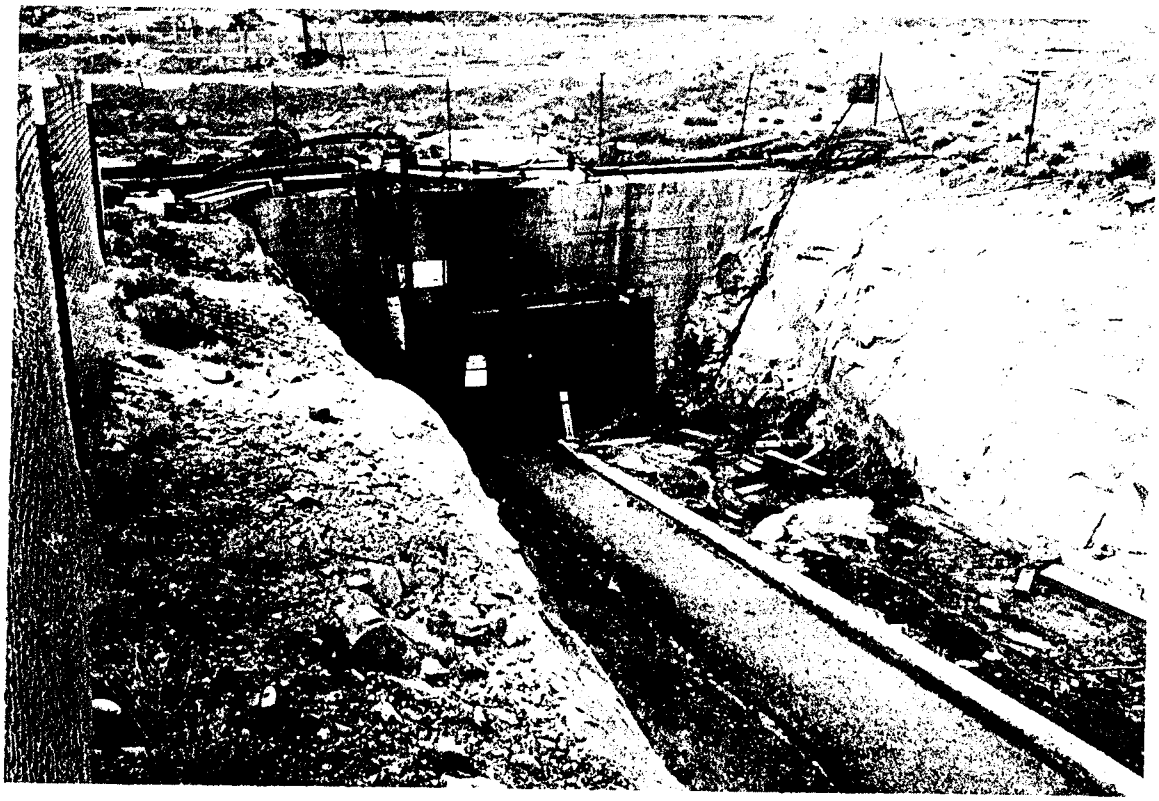

FIGURE 2-7 P-10 DECLINE -TEMPORARILY ABANDONED

Only the P-10 mine produced a substantial amount of water, and the water level has risen to render its workings inaccessible. The deposits at each of the mines, with the exception of NJ-45 and P-13, were mined as completely as the economics of the times would allow.

Previous Reclamation

Anaconda Minerals Co. began a limited reclamation program in 1976. The program consisted of returning most of the overburden removed during the stripping process to mined-out areas of the pits, clearing of stream channels, slope stabilization tests and revegetation of dumps. Each of these processes is described as follows.

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TABLE 2-6

STATUS OF UNDERGROUND MINING OPERATIONS

'ine	Description	Status
.lpine	Small operation - access via 2 adits	Adits permanently plugged with waste
।-1	Small operation - access via 2 adits -3 vent holes - used as an undergroundminer's training school	Adits and vent holes permanently plugged with waste
۷J-45	Small operation begun in 1981 - access via 3 adits from Jackpile pit - 2 vent holes - approximately 1/3 of ore removed	Adits and vent holes temporarily covered - mine workings relatively stable and assumed to be inaccessible
P-7	Large operation - access via P-10 underground drifts - 6 vent holes- vertical emergency escapeway into South Paguate pit	Vent holes temporarily covered - mine workings filled with water and inaccessible
P-9-2	Large operation - access via 5 adits -8 vent holes	Adits, majority of workings, and all but 1 vent hole mined through by advances of South Paguate pit - 1 vent hole open but covered
P-10	Large operation - access via 2,000-foot decline - 11 vent holes	Decline and vent holes temporarily covered - mine workings filled with water and inaccessbile
P-13	Small operation begun in 1981 - access via 2 adits from South Paguate pit - ore body not fully opened - very small percentage of ore removed	Adits and mine workings flooded with water and inaccessible
P 15/17	Large operation approved for development but never begun	No operations conducted
PW 2/3	Small operation - access via 2 adits from North Paguate pit - 2 vent adits into pit	All adits permanently covered with backfill (highwall buttress)
Woodrow	Small operation - vertical shaft with 2 working areas to mine vertical breccia pipe deposit - mining completed in 1956	Shaft backfilled from bottom to top

Source: Anaconda Minerals Company 1982.

Backfilling

During the later years of mining, some overburden was placed into the mined-out portions of the pits. The southern portion of the Jackpile pit and the South Paguate pit received most of this material. Backfilling was also performed for two possible routes for the realignment of State Highway 279. There were no requirements to keep records on the radiological content of the backfill material.

Stream Channel Modifications

In an effort to begin clearing waste from the Rio Moquino's floodplain, approximately 500,000 tons of material from waste dump U on the east side of the river were removed during the last year of mining operations.

Slope Stabilization Tests

Limited tests were performed on the slope of waste dump I to evaluate the ability of biodegradeable matting to inhibit erosion. Special reseeding techniques were performed on the slope of waste dump J. The matting and special reseeding techniques were unsuccessful.

Waste Dump Revegetation

The tops of 17 waste dumps were reclaimed between 1976 and 1979. The tops were contoured to a slight slope, water spreading berms were constructed, large boulders were pushed into piles, 18 to 24 inches of soil were spread, and the dumps were seeded. This work was performed on 18 percent of the disturbed area with varying degrees of success. Further details are provided in the Flora section of this chapter.

Monitoring

Anaconda has performed a comprehensive environmental monitoring program since 1977. The program is summarized in Table 2-7.

GEOLOGY

Physiography

The Jackpile-Paguate minesite is located in mesa and canyon country typical of much of the southeastern Colorado Plateau physiographic province. It is situated in a broad valley of northwest-dipping, sandstone-capped benches pierced by numerous basaltic volcanic necks that rise up to 1,000 feet above the surrounding terrain. Principal landscape components in the area are:

1. Sparsely vegetated, sandstone-capped, flat mesa tops;

2. Steep mesa slopes characterized by approximately 30-degree shale slopes and nearly vertical sandstone slopes, with basal talus from numerous rock falls;

TABLE 2-7

ANACONDA'S ENVIRONMENTAL MONITORING PROGRAM

Item	Monitoring Frequency	Monitoring Parameters	Number of Stations Monitored
Subsidence	Quarterly[a]	Ground movement	89
Surface water	Monthly	29 chemical and radiological parameters[b]	6
Ground water	Monthly	29 chemical and radiological parameters[b]	3[c]
Particulates (radiological)	Monthly	U-natural, Ra-226, Po-210 and Th-230	4
Particulates (non-radiological)	Monthly	Total particulates	4
Gamma	Once after topsoil application	Gamma radiation	100-meter grid on each waste dump
Radon concentration	Monthly	Rn-222	4
Radon exhalation	Twice after topsoil application	Radon release per unit area	100-meter grid on each waste dump
Vegetation	Once	Th-230, Ra-226, Po-210, uranium and radon	Each reclaimed waste dump
Vegetation	Variable	Density, diversity and basal cover	Each revegetated area
Soils	Once	11 chemical and radiological parameters	One composite sample on each reclaimed waste dump
Meteorology	Continuous	Wind speed and direction, temperature and precipitation	1

Notes: a/ On June 9, 1983, subsidence monitoring of P-13 and P-15/17 was discontinued because these mine workings were never developed. At the same time, the monitoring frequency for the P-10 and PW-2/3 mines was reduced to semi-annual.

b/ pH, conductivity, TDS, HCO_3, Cl, SO_4, Na, K, Ca, Mg, NO_3, F, SiO_2, Mn, As, Ba, Cd, Cr, Pb, Hg, Se, Cu, Fe, Zn, Mo, Ni, V, U, Ra-226.

c/ Sampling of the Old Shop Well was discontinued in May 1983. Sampling of the New Shop and #4 wells was discontinued in August 1983. A new ground water monitoring program using nine wells was started in September 1983.

3. Vegetated valley floors cut by numerous arroyos entrenched in fine-grained alluvium; and

4. Densely vegetated, major stream beds.

Prominent landforms of the mine area are: Gavilan Mesa to the east, North and South Oak Canyon Mesas and Oak Canyon to the south, and Black Mesa and numerous deep canyons to the west. Within the lease boundary, elevations range from 5,820 to 6,910 feet.

Stratigraphy

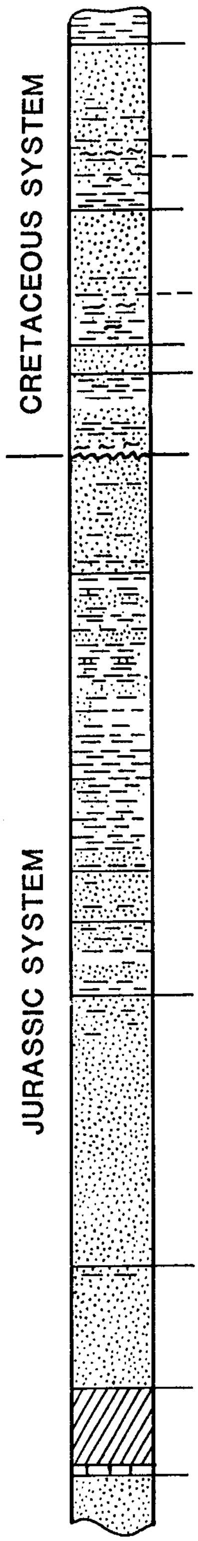
Sedimentary rocks exposed in the area of the minesite range in age from Late Triassic to Late Cretaceous. In addition, Tertiary age diabase dikes and sills and volcanic flow rocks are exposed near the minesite. A generalized stratigraphic column is given in Figure 2-8.

At the minesite, all of the rock units above the lower Mancos Shale have been eroded. The stratigraphy of the mine includes the Morrison Formation, Dakota Sandstone, Mancos Shale, Tertiary igneous dikes and Quaternary alluvium.

The Morrison Formation, locally 600 feet thick, consists of (in ascending order) the Recapture Member, the Westwater Canyon Member, the Brushy Basin Member, and the Jackpile Sandstone Member (Owen et al 1984). The Brushy Basin Member, which is exposed at the minesite, is composed of mudstones up to 350 feet thick with numerous interbedded thin sandstone lenses of restricted extent. The Jackpile Sandstone Member is the uranium mineralization host rock, and is grayish-white, fine- to medium-grained friable sandstone. The Jackpile Sandstone Member is locally more than 200 feet thick (Kittle 1963).

Unconformably overlying the Jackpile Sandstone is the Upper Cretaceous Dakota Sandstone. The Dakota Sandstone intertongues with the overlying lower Mancos Shale, thus creating a stacked series of marine sandstones and shales (Landis et al 1973) shown in Figure 2-8. The sandstones are generally grayish-orange, tan, or yellowish-gray in color, fine- to medium-grained, and have sharp upper contacts and gradational lower contacts (Schlee & Moench, 1963b). The lowermost Dakota unit, the Oak Canyon Member, also contains black shale interbeds, a basal conglomerate in many places, and an upper gray shale portion which has been mapped by some authors as a tongue of the Mancos Shale (Landis et al 1973). The tongues of the Mancos Shale consist of gray friable shale with sparce beds of yellowish-gray friable sandstone. This sequence of Dakota and Mancos intertongues is about 320 feet thick in the mine area.

Quaternary alluvium ranges from 0 to 60 feet thick along the Rios Paguate and Moquino, and is over 100 feet thick along the Rio San Jose (Lyford 1977). The alluvium is composed mostly of silt and fine- to medium-grained sand.



FORMATION	MEMBER	THICKNESS (feet)
Mancos	Main body	
Dakota	Two Wells Sandstone Tongue	60
Mancos	Whitewater Arroyo Shale Tongue	90
Dakota	Paguate Sandstone Tongue	25-30
Mancos	Clay Mesa Shale Tongue	50
Dakota	Cubero Sandstone Tongue	20
Dakota	Oak Canyon	70
Morrison	Jackpile Sandstone	0-220
	Brushy Basin	250-350
	Westwater Canyon	0-50
	Recapture	50-100
Bluff		275
Summerville		120
Todilto		75
Entrada		10

LEGEND

- Sandstone
- Shale and Mudstone
- Limestone
- Anhydrite
- Carbonaceous material

FIGURE 2-8
Generalized Stratigraphic Column of the Jackpile Mine Area

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Structure

The geologic structure at the Jackpile-Paguate uranium mine is relatively simple. Sedimentary rocks dip uniformly about 2 degrees to the northwest into the San Juan Basin. One fault (a minor northwest-trending, normal fault) and two low-amplitude folds are present at the southwestern end of the Jackpile pit (Schlee and Moench 1963). Joints are present in all rocks in the area. Vertical joint sets in the Gavilan Mesa highwall are oriented N. 25 degrees E. and N. 35 degrees W. (Seegmiller 1979a). Vertical joint sets in the North and South Paguate pit areas are oriented N. 25 degrees E. and N. 72 degrees W. (Seegmiller 1979b). Joint spacing ranges from 5 to 15 feet in sandstones and less in shales.

Nature of the Ore Deposit

The Jackpile deposit mined in the Jackpile pit was an elongate, tabular ore body in the Jackpile Sandstone Member, approximately 1.5 miles long and 0.5 miles wide. Individual ore layers rarely exceeded 15 feet in thickness, but stacked layers totaled up to 50 feet (Moench 1963). The dominant ore minerals were coffinite, uraninite and numerous oxidized uranium minerals (Moench 1963).

The deposit mined in the North and South Paguate pits had a known length of over two miles and an average width of several hundred feet. The northern part of the deposit was in the upper one-third of the Jackpile Sandstone Member, while in the southern area, the lower two-thirds of the Jackpile Sandstone Member hosted the deposit. Both the Jackpile and Paguate deposits were formed as uranium minerals precipitated from ground water in the presence of carbonaceous material (Moench and Schlee 1967).

MINERAL RESOURCES

Under Federal regulations, details regarding Indian mineral leases (i.e., production data and royalty information) are confidential. The information contained in this section is presented in general terms to protect its confidentiality. Only the information necessary to provide the reader with an understanding of the importance of this issue is presented.

Remaining Uranium Deposits and Protore Stockpiles

Approximately 23 million tons of uranium resources remain at the minesite as stockpiled protore and unmined deposits. Protore is material that was stockpiled throughout the mining operation because it contains elevated but sub-economic uranium concentrations. (For discussion purposes in this EIS, the term "protore" also refers to the remaining Anaconda "ore" stockpiles. These ore stockpiles have been grouped with the protore stockpiles for discussion because they would be treated in the same manner during reclamation).

Approximately 21 million tons of protore, containing .02 to .059 percent uranium (U_3O_8), exist at the minesite. This material is located on the surface in 23 stockpiles dispersed throughout the mine, as shown in Visual A. The protore was generally segregated according to grade, but some variability in grade exists within each stockpile.

Approximately two million tons of unmined deposits containing .094 to .30 percent U_3O_8 remain at the site. These resources are located in 11 deposits, 3 of which contain 90 percent of the resources. These three deposits are the P15/17, the NJ-45, and the P-13 (Visual A).

The P15/17 deposit is located immediately south of the P-10 mine, and was scheduled to be mined by underground methods until depressed uranium market conditions made this mining uneconomical. Approximately 60 percent of the minesite's unmined resources are contained in this deposit. The deposit remains undeveloped.

The NJ-45 deposit is located under Gavilan Mesa, adjacent to the Jackpile Pit. Anaconda constructed three adits and drove drifts to this deposit in 1981, but mined only a small portion of the resource.

The P-13 deposit is located east of the P-10 mine, adjacent to the South Paguate Pit. Anaconda constructed two adits and drove two drifts to this deposit in 1981, but did not mine the resource. Operations at both the NJ-45 and P-13 mines were suspended when Anaconda closed the overall project.

NON-RADIOLOGICAL MINESITE HAZARDS

Non-radiological hazards at the Jackpile-Paguate minesite include: 1) unstable highwalls, 2) unstable waste dumps, 3) possible subsidence, and 4) underground openings. All of these present a potential physical hazard to humans and livestock as well as a long-term environmental hazard.

Slope Stability

Mine highwalls and waste dumps frequently present safety problems that require carefully designed mitigation procedures. These hazards include:

1. Rockfalls - Toppling and falling of loose sandstone blocks that occurs on all highwalls at the minesite.

2. Rotational failures - These landslides occur in loose rock or soil, and break along concave-upward curved surfaces.

3. Translational failures - These occur in hard rocks, and break along pre-existing zones of weakness i.e., faults or joints. (Note: slope failures may exhibit characteristics of several of these above types.)

Conclusions about slope stability are based on the slope safety factor, which is the ratio between the forces available to resist slope failure and the forces tending to cause this failure. This safety factor is calculated from the friction angle, cohesion and specific (unit) weight of the rock or waste material being analyzed. These properties are determined from field measurements and laboratory tests. The safety factor itself can be calculated using several different methods. Anaconda used the Hoek method while the DOI used the Morgenstern - Price method. The concensus is that these two methods give comparable results.

Generally, a safety factor less than 1.0 indicates instability, while a safety factor greater than 1.0 indicates relative stabilty under the conditions assumed. However, because of the many assumptions used in this EIS and because a margin of safety is needed, the following scale for safety factor and stability is used:

Safety Factor $\leq$ 1.0	Unstable
Safety Factor $>$ 1.0 but $<$ 1.2	Marginally stable
Safety Factor $\geq$ 1.2 but $<$ 1.5	Probably stable
Safety Factor $\geq$ 1.5	Stable

In calculating the safety factor, the effect of cohesion of earth materials is taken into account, because cohesion inhibits slope failure. Cohesion of materials decreases over time, and may approach zeros, but past experience indicates that assuming zero cohesion underestimates slope stabilities. However, assuming maximum (laboratory-determined) cohesion leads to over-estimation of stability. Therefore, the following analyses assume cohesion of 50 percent of laboratory values.

Highwall Stability

The three major areas with highwalls at the mine are Jackpile pit (Gavilan Mesa), North Paguate pit and South Paguate pit (Visual A). Safety factors for them are given in Table 2-8. All three highwall areas are composed of Dakota Sandstone and Mancos Shale. Highwall slopes in the shale units are about 40 degrees, while the sandstone slopes are nearly vertical.

TABLE 2-8

SAFETY FACTORS FOR HIGHWALLS

Pit Highwall	Safety Factors	
	Anaconda[a]	DOI[b]
Jackpile (Gavilan Mesa)	1.40	1.15-1.26
North Paguate	1.63	1.58-1.63
South Paguate	1.87	1.29-3.05

Source: [a] Seegmiller 1981.
[b] Smith 1983.

The Gavilan Mesa highwall is the tallest at the mine; its crest measures just over 500 feet (Figure 2-9). Its slope angle ranges up to 74 degrees, with an overall angle of 49 degrees (Seegmiller 1981a.) This highwall has up to six benches 25 to 50 feet wide. Several tension cracks occur on the first bench below the crest of the highwall. Numerous overhanging and loose sandstone blocks are also present and are most common where several joints intersect with bedding planes and the cliff face. Under present conditions, sections of the Gavilan Mesa highwall are only marginally stable for the long-term. The most likely slope failure would be a rotational one. This type failure would involve most benches and result in a large volume of material sliding to the toe of the highwall.

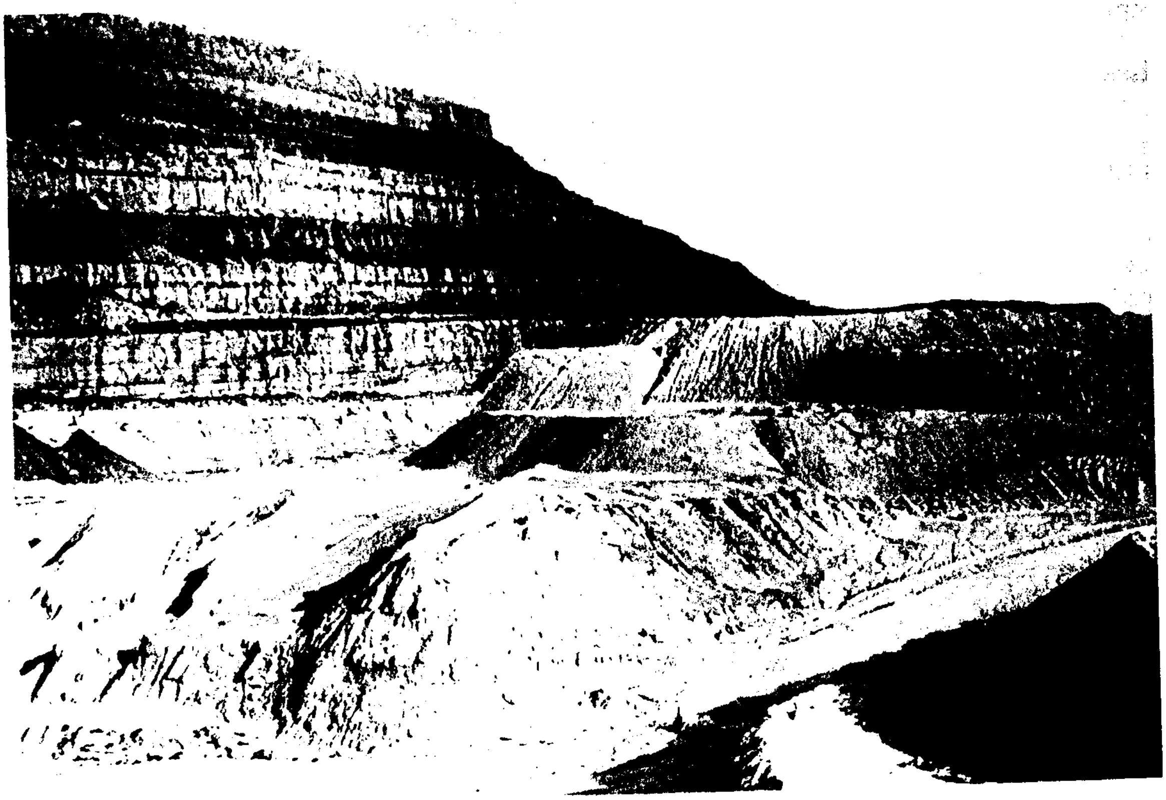

FIGURE 2-9 JACKPILE (GAVILAN MESA) PIT HIGHWALL WITH BUTTRESS MATERIAL AT BASE

Toward the end of mining operations, Anaconda placed waste material against the base of Gavilan Mesa to help stabilize the highwall. The rim of the highwall is not fenced.

The North Paguate pit highwall has a maximum height of 200 feet and a slope angle that ranges up to 70 degrees; the maximum overall slope angle is 55 degrees (Seegmiller 1981a). This highwall has up to three benches 15 to 20 feet wide. It is considered stable for the long term. That portion of North Paguate pit highwall close to the Village of Paguate is fenced with six-foot chain link.

0400076

The South Paguate pit highwall reaches a maximum height of about 300 feet. The slope angle ranges up to 80 degrees, with the maximum overall slope angle being 50 degrees (Seegmiller 1981a). This highwall has up to five benches 5 to 25 feet wide. In places, the South Paguate pit highwall is capped by up to 150 feet of alluvium. Under present conditions, the highwall is probably stable over the the long-term. If a slope failure were to occur, it would most likely be a steep-angled rotational one involving the entire highwall. The rim of the highwall is not fenced.

Waste Dump Stability

Potential hazards resulting from waste dump instability at the mine include: rotational failures, base translational failures, foundation spreading and piping. These waste dump failures could expose radiological material and thus present a health and environmental hazard. The material properties of eight waste dumps have been analyzed to assess existing stabilities (safety factors), including rotational failures through the dump toes, and translational failures along the dump bases (Seegmiller 1980b). The eight waste dumps analyzed are those where the most severe stability problems could be expected. Safety factors for the eight dumps under rotational and base translational failure are given in Table 2-9. These safety factors are applicable only under short-term conditions (with cohesion present) and are not applicable to long-term stability (with diminishing cohesion). Saturation of a dump in the climate at the minesite is not considered likely, so conclusions about rotational failure assume dry conditions.

TABLE 2-9

SAFETY FACTORS FOR WASTE DUMPS

Dump	Rotational Failure (dry conditions)[a]	Base Translational Failure	
		Static[a]	Dynamic[b]
FD-2	1.5	.84	<1.1
I	2.1	29.00	>1.1
South Dump	1.6	29.00	<1.1
T	2.2	29.00	<1.1
U	3.0	29.00	<1.1
V	1.4	29.00	<1.1
Y	4.0	29.00	>1.1
Y_2	3.5	29.00	<1.1

Source: Seegmiller 1980b.

Notes: [a]Minimum safety factor of 1.5 or greater.
[b]Minimum safety factor of 1.1 or greater

0400077

The Seegmiller analysis (1980b) indicates that, under conditions assumed, all dumps are at least "probably stable" with regard to rotational failure, and that all dumps except FD-2 are stable in regard to base translational failure under static conditions. The analysis also indicates that the two most critical dumps, in terms of stability, are FD-2 and V dumps.

FD-2 is a 270-foot-high dump composed of shale and Tres Hermanos Sandstone (Figure 2-10). It lies on a steep slope on the south side of Gavilan Mesa. Tension cracks are present near the crest. Although Seegmiller calculated a safety factor of 1.5 (rotational failure under dry conditions), this dump appears to be just marginally stable. If one assumes no cohesion, FD-2 is unstable with regard to rotational failure. If the dump were to fail, a slump would probably displace the upper one-third to one-half of the dump, with the displaced material sliding to the base of the mesa.

V dump, approximately 215 feet high and composed mostly of Jackpile Sandstone, is located near the Rio Moquino (Figure 2-11). The southwest side of this dump shows slide scars near the dump toe. Seegmiller's analysis shows this dump to be stable under short-term conditions (cohesion present), but under zero cohesion conditions, this dump has a safety factor against rotational failure of 1.0, i.e., it is unstable.

Slopes sometimes fail when the materials underlying them cannot hold up the weight of overlying materials. This is called failure by foundation spreading. This has not been a problem at the Jackpile-Paguate mine in the past, and is not expected to be a problem except at FD-2 dump, where fissures in materials underlying the base of the dump suggest foundation spreading.

Piping is a process in which surface water flows downward through unconsolidated material, eroding the material to form a hollow tube or pipe. Piping on waste dump tops is common, especially where water ponds against erosion control berms. Piping causes geologic hazards at the minesite in two ways:

1. Areas around large, deep pipes are unstable, leading to a greater liklihood of human or livestock accidents.

2. Piping at dump crests has initiated large gullies at D,I,T,V and South dumps. These gullies are sources of rockfalls, small earth slides and high-velocity concentrated runoff.

Subsidence

Information on existing ground subsidence above the underground mine workings is presented in Table 2-10. As of June, 1986, a maximum of 4.16 inches of subsidence has occurred at one station over the 1500 area of the P-10/7 mine (Anaconda 1984).

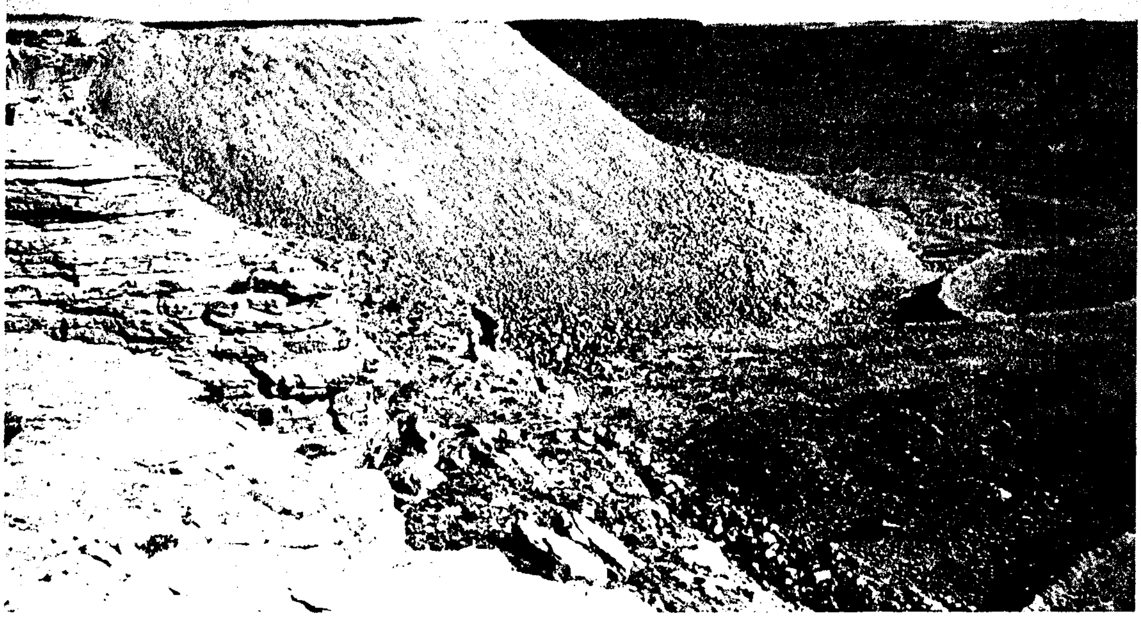

FIGURE 2-10 FD-2 DUMP ON EAST SIDE OF GAVILAN MESA

FIGURE 2-11 V DUMP SHOWING ACTIVE EROSION

0400079

TABLE 2-10

SUBSIDENCE DATA ON UNDERGROUND MINES - JACKPILE-PAGUATE MINESITE

Mine	Depth (Feet)	Mining Height (Feet)	Overlying Strata[a]	Ground Surface	Subsidence Monitoring Grid	Subsidence
Alpine	70	9 to 12	JSS, DS	Undisturbed	None	None observed
H-1	140 to 200	8 to 13	JSS, DS, MS	Undisturbed	None	None observed
NJ-45	35 to 320	10	JSS, DS, MS	Disturbed - pit and highwall	None	None observed
P-9-2	140 to 160	9 to 20	JSS, DS, MS	Undisturbed	None	None observed
P-10/7 (and P-13)	200 to 600	9 to 45	JSS, DS, MS COLL	Mostly disturbed	81 stations at Hwy 279 (estab. 1976)	Range: -0.02 to -4.16 inches
PW 2/3	40 to 140	9 to 15	JSS, DS, MS	Disturbed - pit	8 stations (estab. 1978)	Range: -0.04 to -0.68 inches
Woodrow	Up to 200	-- [b]	Backfill	Disturbed	None	None observed

Sources: Seegmiller 1981d, Anaconda Minerals Company 1986.

Notes: a/ JSS=Jackpile Sandstone; DS = Dakota Sandstone; MS = Mancos Shale; COLL = Colluvium.
b/ -- = Unknown.

0400080

Seegmiller (1981b, c, d) studied several possible problem areas at the mine. These are the A and B stopes of the Alpine mine, the 1400B stope of the P-10/7 mine and the A and B stopes of the PW 2/3 mine. Seegmiller's estimates of subsidence at these sites are shown in Table 2-11. The data indicate that all areas, except for the area above the P-10 mine decline, are in a "low risk" category with regard to subsidence. The P-10 decline could be subject to subsidence of significant magnitude and rate. This is because, from the surface to 680 feet down the decline, the ratio of overburden to mining height is less than 10:1. As a general rule, mine voids with values of this ratio of less than 10:1 may be unstable without support.

TABLE 2-11

PREDICTED MAGNITUDE AND RATE OF SUBSIDENCE OVER POSSIBLE PROBLEM STOPES AT UNDERGROUND MINES

Mine Area	Probable Subsidence	Probable Rate
Alpine Mine, A stope	6"	Very Slow
Alpine Mine, B stope	4"	Very Slow
PW 2/3, A stope	6"	Very Slow
PW 2/3, B stope	12"	Very Slow
P-10/7, 1400B stope	1"	Zero to Very Slow

Source: Seegmiller 1981b,c,d.

Underground Openings

The Alpine mine was accessed by two adits that have been sealed by backfilling with 5 to 10 feet of waste material. No bulkheads were placed in either adit. The area surrounding the adits has been backfilled to above the portals.

The H-1 mine was accessed by two adits, one of which has been backfilled 20 feet inward from the portal. The other adit is sealed by waste material only at the portal. The three ventilation shafts have been backfilled from bottom to surface and are covered by a 5-foot-high surface mound.

The NJ-45 mine was accessed by four adits, three of which accessed the workings, while only the portal of the fourth adit was constructed. Ventilation was supplied by two 42-inch ventilation shafts. All mine workings are barricaded but not backfilled.

The P-9-2 mine was accessed by five adits and ventilated by eight 42-inch ventilation shafts. Open-pit operations progressed through the mine workings and seven of the ventilation shafts. The remaining ventilation shaft is still open. The mined areas have been backfilled above the level of the remaining underground workings.

The P-10/7 mine was accessed by one decline and an emergency escapeway that leads into the South Paguate pit. It was ventilated by seventeen 42-inch ventilation shafts. All mine entries are barricaded but not backfilled.

The P-13 mine was accessed by two adits that are still open. However, this mine has flooded naturally.

The PW 2/3 mine was accessed by four adits, the portals of which have been backfilled. Subsequent backfilling has covered three of the portals.

The Woodrow mine was accessed by a 225-foot deep shaft. The shaft has since been backfilled to the surface.

RADIATION

Introduction

This section describes the existing radiological environment in and around the Jackpile-Paguate uranium mine. A primer on radiology, including the terminology used in this EIS, is given in Appendix C.

Standards

No specific standards exist for the release of radiation and radioactive materials from uranium mining operations, nor do specific standards exist for post-reclamation radiation levels. Standards have been developed by the Federal government for active uranium mills, inactive uranium mills, public drinking water systems and point-source discharges of water (Table 2-12). In addition, the U.S. Federal Radiation Council, (since merged into the U.S. EPA) published general radiation protection guidelines on May 13, 1960. These guidelines provided that 1) there should not be any man-made radiation exposure without the expectation of benefit resulting from such exposure, and 2) that every effort should be made to encourage the maintenance of radiation doses as far below the guidelines as practicable (what is now known as the ALARA principle). These standards and guidelines provide a useful comparison by showing the levels of radiation and radioactive materials that are considered acceptable for other situations.

Sources of Radiation of the Minesite

Uranium and all members of its decay chain are present everywhere in low concentrations in air, soil and water. However, special geologic and hydrologic conditions at the minesite have allowed uranium from the ground water to be deposited in much higher concentrations than background levels.

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TABLE 2-12

FEDERAL RADIATION STANDARDS

Source of Standard	Subject	Standard[a]	
		Item	Limit
Nuclear Regulatory Commission (10 CFR 20.105 and 20.106)	Permissible levels of radiation in unrestricted areas[b]	Annual whole body dose to an individual	0.5 rem (equivalent to 57 microroentgens per hour)
		Radon-222	3 pCi/l (individual)[c] or 1 pCi/l (population)
Environmental Protection Agency (40 CFR 141.15)	Maximum levels for radium-226, radium-228 and gross alpha particle activity in community water systems	Combined radium-226 and radium-228	5 pCi/l
		Gross alpha (including radium-226 but excluding radon and uranium)	15 pCi/l
(40 CFR 192)	Health and environmental protection standards for uranium mill tailings	Radon-222 release from uranium by-product materials	20 $pCi/m^2 \cdot s$[b]
		Radon-222 concentrations at the boundary of a disposal site	0.5 pCi/l
		Radium-226 in land averaged over 100 square meters	5 pCi/g (over the first 15 centimeters of soil below the surface)[c]
			15 pCi/g (averaged over 15-centimeter-thick layers of soil more than 15 centimeters below the surface)
		Radon daughter and gamma levels inside buildings at abandoned mill sites	.03 WL and 20 μR/h[c]
(40 CFR 440.52)	Concentration of pollutants discharged in drainage from uranium mines, either open-pit or underground (<u>in situ</u> leach mines excluded)	Radium-226 (dissolved)	10 pCi/l (daily maximum) 3 pCi/l (30-day average)
		Radium-226 (total)	30 pCi/l (daily maximum) 10 pCi/l (30-day average)
		Uranium	4 mg/l (daily maximum)[c] 2 mg/l (30-day average)

Notes: [a] Air standards are above background; water standards include background.
[b] 10 CFR 40.13 specifically excludes "... unrefined and unprocessed ore..." (i.e., mines and mining).
[c] Units of measurement: pCi/l = picocuries per liter; $pCi/m^2 \cdot s$ = picocuries per square meter per second; pCi/g = picocuries per gram; WL = working level; μR/h = microroentgens per hour; mg/l = milligrams per liter.

The decay of some of the uranium in the ore at the minesite has led to the presence of all members of uranium decay series in the deposits. Because this decay has been occurring over a very long period of time, it has reached a state of "secular equilibrium," i.e., the radioactivity of each member of the decay chain is the same as that of the uranium-238, the parent.

During mining operations, the ore with the highest concentration of uranium was removed, thereby decreasing somewhat the total amount of radiation produced at the site. However, the mining operation increased the rate at which the radiation was released into the immediate vicinity of the site by bringing the radioactive ore to the surface (i.e., by removing the shielding of the overburden) and by altering the ore's chemical and physical properties. The sources of radiation at the site (other than normal background) are protore, ore-associated waste and the unmined portions of the uranium ore deposit. The radiological characteristics of surface materials at the minesite are shown on Table 2-13.

The protore at the minesite consists of approximately 15.5 million tons of rock containing 0.02 to 0.059 percent uranium oxide (U_3O_8). The protore is located in 23 stockpiles inside and outside of the open pits. [In mining, the concentration of all uranium isotopes (U-234, U-235, U-238) present in a certain amount of rock is expressed as if the isotopes existed as an equivalent amount of uranium oxide (U_3O_8). This U_3O_8 equivalent is expressed as a percentage by weight.]

The ore-associated waste consists of an unknown quantity of rock containing 0.002 to 0.02 percent U_3O_8. Records were not required on the exact uranium content, nor on the deposition sites of the ore-associated waste. This waste was mixed indiscriminately with the overburden and placed in the 32 waste dumps on the site, or was used as backfill material. It is estimated that 50 million tons of ore-associated waste remain at the site, but this number might be in error by a substantial amount.

The site also contains about 2 million tons of unmined uranium resources containing 0.094 to 0.3 percent U_3O_8 and an unknown amount of resources below 0.094 percent. These resources have not been disturbed by mining operations and contribute little to the amount of radiation released from the site because they are shielded by the overburden.

The minesite has an average of 70 picocuries per gram of radium-226 and uranium-238. These values are about 47 times higher than the average background levels and about 14 times higher than the U.S. Environmental Protection Agency's mill tailings standard (40 CFR 192).

TABLE 2-13

RADIOLOGICAL CHARACTERISTICS OF SURFACE MATERIALS
AT THE JACKPILE-PAGUATE MINE

Site Designation[a]	Area (Acres)	U-Natural Analysis μg/gm	U-Natural Activity pCi/gm	Gamma μr/hr Average
Dump A	23	4.50	3.20	11
Dump B	71	2.70	1.90	10
Dump C	21	2.70	1.83	5
Dump D	14	4.05	2.74	5
Dump E	12	1.50	1.01	5
Dump F	73	4.03	2.73	5
Dump G	49	5.82	3.94	5
Dump H	7	146.80	99.38	29
Dump I	57	10.00	7.00	5
Dump J	15	10.66	7.22	75
Dump K	22	20.30	13.74	7
Dump L	58	5.50	3.72	5
Dump N	48	42.00	30.00	9
Dump N2	16	200.00	150.00	30
Dump O, P, P1, P2	35	3.12	2.11	12
Dump Q	52	160.00	120.00	68
Dump R	14	11.00	8.00	24
Dump S	96	2.79	1.89	10
Dump T	32	3.90	2.80	9
Dump U	61	34.29	23.21	52
Dump V	51	13.94	9.44	34
Dump W	7	2.50	1.80	10
Dump X	9	18.00	13.00	5
Dump Y	30	33.42	22.62	13
Dump Y2	15	4.20	3.00	5
South Dump	175	4.90	3.50	8
FD-1	168	2.70	1.90	10
FD-2	25	45.00	32.00	3
FD-3	10	14.00	10.00	28
17BC (SP-17BC)	15	220.00	150.00	581
6A (SP-6-A)	17	200.00	140.00	388
6B (SP-6-B)	9	130.00	93.00	383
J1 (J-1)	9	94.00	67.00	155
J2 (J-2)	8	490.00	350.00	606
17D (MILLED)	3	520.00	370.00	198
1B (1-B)	9	140.00	100.00	237
2C (SP-2-C)	12	110.00	79.00	422
10 (10 DIKE)	3	390.00	280.00	506
2D (SP-2-D)	6	180.00	130.00	419
1C (SP-1-C)	5	61.00	44.00	227
1A (SP-1-A)	20	31.00	22.00	161
2E (2-E)	3	220.00	160.00	451
SP-1	9	130.00	95.00	354
PLG	3	5.00	3.60	210
4-1	8	77.00	55.00	266
SP-2 (MILLED)	12	180.00	130.00	300
SP-2B (MILLED)	2	610.00	440.00	164
TS-1	21	4.90	3.50	8
TS-2A	5	4.90	3.50	18
TS-2B	6	2.90	2.10	6
TS-3	19	3.60	2.60	11
Topsoil Borrow Site	43	4.10	2.90	17
Jackpile Pit				
. North	159	28.00	20.00	128
. Central	158	180.00	130.00	107
. South	158	760.00	540.00	165
N. Paguate Pit				
. West	47	47.94	32.45	27
. Central	47	53.00	38.00	113
. East	46	85.00	61.00	79
S. Paguate Pit				
. West	134	4.30	3.10	20
. Central	133	17.00	13.00	29
. East	133	24.00	17.00	72
Housing Area	19	8.00	6.00	22
Shop Area	17	24.00	17.00	36
Old Shop Area	4	37.00	27.00	44
P-10 Adit Area	3	120.00	86.00	192
Pit Offices	2	31.00	22.00	44
Park Lot at SP-1	7	56.00	40.00	78
Park Lot at SP-2	12	32.00	23.00	102
Rail Spur (on lease area)	7	180.00	130.00	104
Roads	88	35.00	23.70	75

Source: Anaconda Minerals Co. 1982.

Note: [a]Original designations supplied by Anaconda; designations in parentheses correspond to Visual A in this EIS.

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The protore piles contain concentrations up to 165 picocuries per gram : both radium-226 and uranium-238. Small localized pockets may exceed) picocuries per gram for these elements.

Radiation Exposure Pathways and Existing Levels of Radiation

The principal potential pathways for human exposure to radiation from e minesite are as follows:

1. Direct Gamma Radiation--Direct exposure to radiation emitted by e radioactive material on the surface of the ground at the site. posure is to the whole body, but applies only to people at the minesite self. (Direct exposure to beta radiation is also a potential exposure ıthway, but the health impacts from direct gamma exposure far exceed ıose of beta radiation. All measures taken to reduce direct external ımma radiation would also reduce external beta radiation. Therefore, ırect external beta radiation is not analyzed any further in this ocument.)

2. Ambient Radon--Inhalation of radon-222 and its radioactive decay roducts (progeny) from the continuous decay of radium-226 in the protore nd ore-associated waste; exposure is primarily to a portion of the lungs rom radon-222 progeny.

3. Particulates--Inhalation of windblown particles containing ·adioactive elements; exposure is to the lungs from the progeny of the ıranium-238 decay chain.

4. Water--Consumption of surface or ground waters containing radioactive elements; exposure is primarily to the bone and stomach from ıll progeny of the uranium-238 decay chain.

5. Ingestion--Consumption of meat and vegetables contaminated with radioactive elements.

Any of the exposure pathways mentioned above would be created by radioactive material that has been removed from the site by water erosion, spillage along ore haul routes or purposely taken from the site.

Direct Gamma Radiation

Gamma rays are continuously emitted from the radioactive decay of many elements contained at the minesite in protore and ore-associated waste. The principal gamma emitters are decay products of uranium-238, mainly bismuth-214 and lead-214.

Gamma rays cannot penetrate long distances through dense material. For example, one foot of compacted earth shields about 90 percent of the gamma radiation (Ford, Bacon & Davis Utah, Inc. 1977). Therefore, only the gamma rays that are produced at or very near the ground surface enter the atmosphere. In the atmosphere, gamma rays may travel up to 500 yards before they are absorbed by the air; therefore, people must be within 500 yards of the gamma-emitting source to be exposed. The closer a person is to the source, the greater the dose received.

Exposure to gamma rays can be very hazardous because gamma can penetrate the human body and expose all organs. The potential damage to these organs from ionizing radiation is discussed in Appendix C. The Nuclear Regulatory Commission (10 CFR 20.105) limits gamma exposure in unrestricted areas to no more than 0.5 rem per year [0.5 rem/year = 57 microroentgens per hour (uR/h)] over background. As previously mentioned, this standard does not apply to uranium mines. However, it does put the following discussion of gamma levels in perspective.

An aerial survey was conducted at the minesite and the surrounding areas to determine the levels of gamma radiation being emitted from the site and vicinity, to discover if winds had spread radioactive material offsite, and to locate any spills. This aerial survey was used to determine background gamma radiation levels to be used as a basis for reclamation evaluation. The survey was performed in July and August, 1981, by the Energy Measurements Group of EG&G (Jobst 1982). Corrections were made in the data for the altitude of the helicopter, terrestrial radiation, and cosmic radiation, to obtain an exposure rate 3 feet above the ground due to gamma sources in the soil. The results of the survey are shown on Maps 2-1 and 2-2.

The background gamma exposure rate is 13 uR/h; most of the area outside of the minesite, including the Village of Paguate, is at background levels.

Those areas that have exposure rates above background values are shown on Maps 2-1 and 2-2. Slightly elevated (14 to 18 uR/h) levels were measured in all major drainages above and below the minesite. A followup ground survey showed the high exposure rates in these areas are primarily due to spillage of ore and to natural outcrops of uranium- bearing rock. Conditions at areas 1, 3, 4, 7 and 8 on Map 2-1 resulted from the mining operations. More detail for each of these high exposure areas is provided in Table 2-14.

The exposure rates within the minesite are shown on Map 2-2. The maximum exposure rate of 480 uR/h is approximately 37 times the background level of 13 uR/h, while the average exposure rate of 50 uR/h is approximately 4 times background. The protore piles have the highest exposure rates. Areas that have been covered with soil, such as dumps C through G, have exposure rates at or below 18 uR/h.

Paguate (Quirk) Reservoir was studied to determine the concentration of radioactive elements in the sediment. A surface gamma survey consisting of 1,500 data points was conducted in and around the reservoir (Eberline Instrument Corp. 1981). Also conducted was a subsurface gamma survey consisting of 47 drillholes (a maximum of 30 feet deep) and 7